4.2 – DNA: Watson and Crick Model, Forms of DNA (A, B and Z)

DNA: Watson and Crick Model

- By using X-ray distraction and chemical observation Watson and Crick [1953] proposed a model for a DNA molecule which has widely accepted.
- According to this model a DNA molecule composed of two long polypeptide chains.
- The two chains runs in opposite direction that's why they are antiparallel to each other one polypeptide chain runs in 5'-3' direction and another is in 3'-5' direction.
- In such a structures sugar - phosphate backbone lies on the outside of the molecule while the nitrogenous bases of the two chains are projected towards the centre.
- Watson and Crick shared the Nobel Prize in 1962 for their discovery, along with Maurice Wilkins who had continued research to provide a large body of crystallographic data supporting the model.
- Working in the same lab, Rosalind Franklin (1920 - 1958) had earlier produced the first clear crystallographic evidence for a helical structure.
- Crick went on to do fundamental work in molecular biology and neurobiology.
- Watson become Director of the Cold Spring Harbor Laboratory, and headed up the Human Genome Project in the 1990s.

Base Pairing

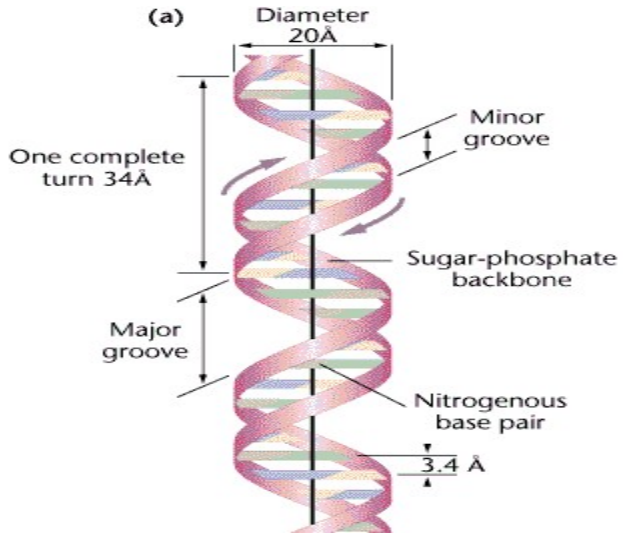
- It is observed that the nitrogen bases present on one strand pairs with the nitrogen bases of opposite strands.
- Purine base A always pairs with pyramidine base T with double hydrogen bond [A=T]. And the purine base G always pairs with the pyramidine base C with triple hydrogen bond [G≡C].
- The nitrogen bases along with the hydrogen bonds make up the rungs the ladder. These are also referred as transverse bars.
- In the DNA molecule total number of purine base is always equal to the total number of pyramidine base. This is called Chargaff's Rule; it gives 1:1 ratio.

Polarity of strands

- Each strand of DNA has polarity.
- One end is considered as 5' or C-5 and were as other is 3' or C-3 end.
- At 5' end there is free phosphate group while at the s' end there is free -OH group, one strand of DNA is oriented in 3'-5' and complementary strand is in 5'-3'.
- Each nucleotide present on the DNA strand is joined with next nucleotide by means of phospho-diester linkage.
- The two strands of DNA are considered as antiparallel and the strand runs parallel to each other.

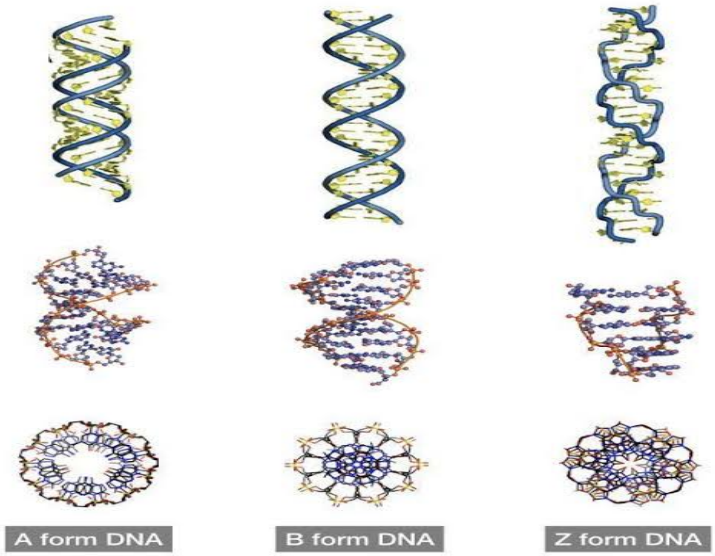
- The base sequence present on one strand of DNA decides the base sequence of the other strand; the strands are regarded as complementary strand. This is because of definite base paring.

Major and Minor grooves



- DNA strands undergo coiling around a central axis of the double helix results in the formation of major and minor grooves by the twisting of the two strands.
- The diameter the DNA molecule is $20A^0$.
- One loop for spiral turns of the molecule measures $34A^0$ and is called pitch of DNA molecule.
- Each loop contains ten pairs of nucleotides. Therefore the distance between two successive nucleotide pairs is $3.4A^0$.

Forms of DNA



- The most common form of DNA which has right handed helix proposed by Watson and Crick is called B-form of DNA or B-DNA.
- In addition DNA can exists in different forms such as A, B, C, D, H, Z forms. The difference in this forms to associated with
  - The number of base pairs per turn of DNA helix.
  - The angle between each base pair.
  - The helical width or diameter the DNA molecule.
  - The Handedness [left or right] of double helix.

The A-Form of DNA (A-DNA)

- Structure of A-DNA has been proposed by Rosalind Franklin.
- The A-form of DNA is found at 75% relative humidity in the presence of Na+, K+ or Ca+ ions.
- It contains eleven base pairs as compared to ten base pairs of B-DNA which tilt from the axis of helix by 20°.
- Due to this displacement the depth of major groove increases and that of minor groove decreases.
- The distance of per turn is $28A^0$.
- A single turn consist 11 nucleotide base pairs so the distance between two base pair is $2.6A^0$.
- The diameter of whole DNA is $26A^0$.
- The A-form is metastable and quickly turns to the D-form.

The B-Form of DNA (B-DNA)

- Structure of B-form of DNA has been proposed by Watson and Crick.
- It is present in every cell at a very high relative humidity (92%) and low concentration of ions. It has antiparallel double helix, rotating clockwise (right hand) and made up of sugar- phosphate back bone combined with base pairs or purine-pyrimidine.
- The base pairs are perpendicular to longitudinal axis of the helix. The base pairs tilt to helix by 6°.
- The distance of per turn is $34A^0$ called pitch of DNA.
- A single turn consist 10 nucleotide base pairs so the distance between two base pair is $3.4A^0$.
- The diameter of whole DNA is $20A^0$.
- The B-form of DNA is metabolically stable and undergoes changes to A, C or D forms depending on sequence of nucleotides and concentration of excess salts.

The Z-Form of DNA (Z-DNA) or Left Handed DNA

- Robbert Wells has been proposed a left handed DNA structure.
- On the other hand in 1979, Rich and coworkers at MIT (U.S.A.) obtained Z-DNA by artificially synthesizing in the form of crystals.

- They proposed a left handed double helix model with zig-zag sugar-phosphate back bone running in antiparallel direction.
- Therefore, this DNA has been termed as Z-DNA.
- The Z-DNA has been found in a large number of living organisms including mammals, protozoans and several plant species formed by high concentration of salt.
- It is a long DNA having 7^0 angle of tilt.
- The distance of per turn is $44A^0$.
- A single turn consist 12 nucleotide base pairs so the distance between two base pair is $3.7A^0$.
- The diameter of whole DNA is $18A^0$.